

telephony

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Section analysis: a cost-effective approach to cable maintenance

Section analysis is a disciplined, methodical system for troubleshooting and recovering faulted cable pairs.

While it is not always the fastest approach, it usually is the most cost-effective solution

DON McCARTY

SECTION ANALYSIS is a disciplined, methodical system for troubleshooting and recovering faulted cable pairs. Though it's not always the fastest approach to service restoration, in the short term it can be the most cost effective by far, as well as actually taking the least labor hours in the long run.

In most operating companies today, the average cable repair technician sees his or her first duty as being to restore service as quickly as possible. A number of inventive short-cuts to speedy restoration have been discovered—most of them at the expense of efficient outside plant maintenance and operation. A faulted pair not repaired is a pair lost to service, and a trouble not located and fixed will invariably spread to adjacent pairs and cause repeat calls and more repeat calls for the same basic trouble.

With section analysis, however, the basic trouble is analyzed and repaired at first report. The net result is that more pairs are maintained available for present or future service, and the trouble doesn't have the chance to spread to adjacent pairs, so the costs of repeat service calls or unnecessary cable route reinforcement are avoided.

Achieving this, of course, demands a commitment to the section analysis concept. That includes providing cable repair personnel with the knowledge and the tools to do the job, and emphasizing to them the change in troubleshooting philosophy it entails.

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With proper management support, a well-trained and properly equipped cable repair technician can isolate a trouble section, analyze the type of trouble and the probable cause, and get to the problem quickly to effect a permanent repair.

The tools it takes

The right tools speed analysis and location. A section analysis package offered by Dynatel includes three complementary cable fault locating instruments that indicate conditions in a cable section and guide the technician to the point at which corrective action is required. The devices are a resistance fault locator, an open (or open and split) locator, and a cable and sheath fault locator.

The resistance fault locators measure metallic-type faults as high as 1.5 million ohms. They test and analyze

cable conditions and locate faults to a distance of 100,000 ft. (approximately 18 miles). Shorts, grounds, crosses and cross-battery also can be located.

The first steps in section analysis are performed with a resistance fault locator. It tests cable, analyzes the type and extent of troubles and displays the distance to a faulted section.

Once primary testing and location are done and the trouble section defined, a capacitance bridge can be used to analyze and locate opens in the section. Used with the resistance fault locator, the capacitance bridge will reveal any water that may have entered the sheath.

With the trouble section determined, the exact route and distance between accesses must be determined.

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FIG. 1 Diagram shows how to measure the amount of water in a cable.

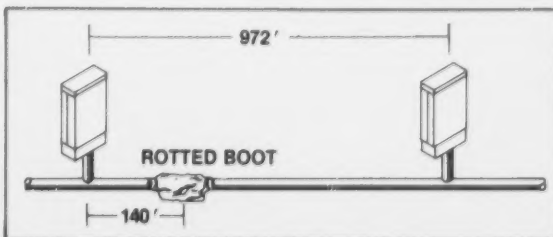
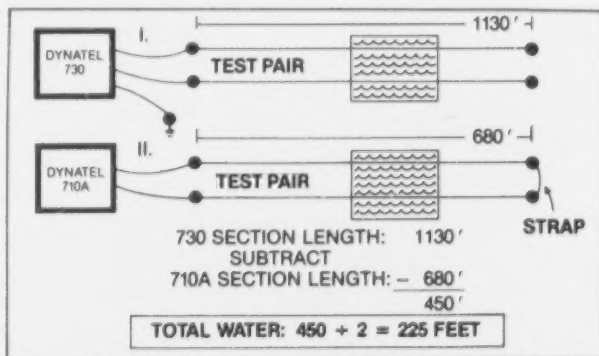


FIG. 2 Diagram illustrates how rotted boot exposes the conductors to moisture.

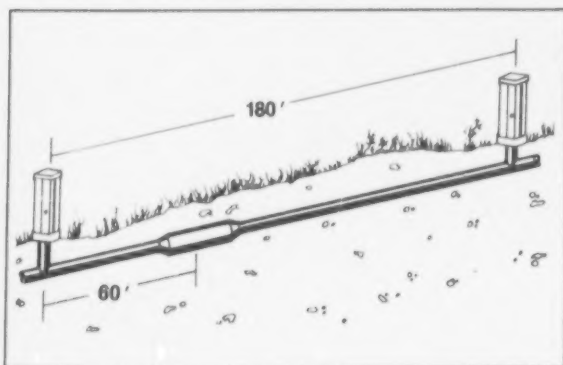


FIG. 3 At this installation a VOM indicated a sheath fault. The capacitive length is 260 ft. and the correct resistive length is 180 ft. Conductor faults were indicated 60 ft. from the hookup.

mined for accurate location measurements. A cable and sheath fault locator will allow the cable path to be accurately marked and measured. Characteristics such as slack-loops and butt splices can be identified so that exact distances can be determined. When a cable and sheath fault locator indicates a sheath fault in the test section, an earth frame guides the technician to the fault site.

The importance of training

No equipment is any good unless the cable repair technician knows how to use it. Part of the support maintenance personnel need from their operating companies is thorough training, not only in the use of individual test equipment, but also in the use of all their equipment as an interrelated cable analysis system. Several test equipment manufacturers have customer training programs that will help achieve this.

But there's more to it than equipment and training. A management commitment to section analysis is necessary, and that commitment has to be instilled in the craftspeople who will carry it out.

Suppose the technician dispatched on a subscriber complaint finds the pair defective between the "work-out" terminal and the field. It tests OK back to the central office. The quick fix here is to "cobb" the pairs, or simply cut them off to the field. The subscriber's happy—service has been restored. The repair technician's happy—it took only a few minutes. The supervisor's happy—work can begin on the next case.

But the outside plant is a potential disaster. That trouble has been circumvented for one subscriber, but its cause is still somewhere out in the field. Whatever it may be—water, a cable nick, a defective splice—it's still there, and it's going to be heard from again.

Or suppose the subscriber pair is found to be faulted back toward the

central office. The common solution is to cut to clear, changing over to a new pair.

The customer's back in service and the job is done. But the trouble's not repaired.

Or the pair can be transposed, or "rolled," if a trouble section can be isolated and a good pair through it is attached to the subscriber pair at both ends. Once more, the customer's back in service and the trouble's still there.

There's a limit to how long this sort of thing can go on before the route runs out of spare pairs and reinforcement becomes necessary. That's expensive—and often unnecessary where good maintenance and recovery practices keep things working.

Now, let's look at how section analysis would be applied in this same case of trouble.

First, the technician must isolate the trouble section. In order to find a pair that goes around the trouble—or to be able to run a separate good pair if necessary—the trouble has to be isolated between accesses. There the true analysis can begin.

Next, the technician must develop a physical and conceptual picture of the cable before doing any digging or opening. Look at the situation. Is the section level or running up or downhill? Are there signs of recent construction work or digging in the cable path? What kind of cable and pair count is involved? And before going too far, the length, gauge and temperature should be accurately determined, either by maps or direct location and measurement.

The technician should use maps or sequential markings on the cable. If this information is unsatisfactory, he must locate the cable path and measure the length with a wheel or tape.

Some possibilities and expectations should be apparent already. If there is water in the cable, it would tend to collect on the downhill side.

If a recent dig has taken place near the path, that's a logical place to suspect a nick.

A solid understanding of cable makeup is an invaluable tool in section analysis. The cable is manufactured for good transmission characteristics, but analysis of changes in these characteristics are the primary clues to why a cable has failed.

For example, an average exchange cable, either air core or filled, will be all one gauge. Any gauge substitution will measure a different electrical footage over its physical length. A total of 900 ft. of 24 gauge with 200 ft. of 22 gauge substituted will measure 825 with a bridge. Analysis of this occurrence also indicates 2 splices in the section.

The average mutual capacitance of an air core cable is .083 microfarads per mile. Any intrusion of water will increase the capacitance, and make the cable appear longer than the actual physical length of the section.

Once the physical distance of the section has been determined, the first step is to measure the distance with a resistance fault locator. Any subtle difference between this measurement and the actual length indicates a gauge change. If the physical distance is the same, measure the capacitive distance with the capacitance bridges. This will indicate any amount of water in the cable.

Battery on the shield means a portion of the section needs to be purged or replaced. Any sheath faults can be identified with a device designed for that purpose.

The next test is to establish the extent the dielectric integrity of the cable has been violated. For this, a resistance bridge is the first test instrument used on the section.

Using the bridge, the technician can analyze the troubles in the test section. A pattern of symptoms will emerge and help identify the type of trouble.

For instance, if several light faults, mostly ring-battery crosses with the tips clear, are detected, there's water in the cable.

If several high-resistance troubles with shorts, crosses and grounds on both tip and ring—and some opens—are detected, water again is indicated—but this time it's probably in a splice or encapsulation.

And both light and solid troubles with many shorts and opens would indicate cable damage.

To check the integrity of the sheath the technician removes the

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Table 1**Cost to replace 972 ft. of cable:**

Cable	\$ 6306.34
Splices (2 @ \$1404.00 each)	2808.00
Placing	1633.00
Total	\$10,747.34

Cost of repair on splice:

Splice	\$1404.00
Pit	500.00
Total	\$1904.00

Savings:

Cost of replacement	\$10,747.34
Cost of splice repair	1904.00
Savings	\$ 8,843.34

bonds at both ends of the section and test with a voltmeter. If there is an indication of battery on the shield—5 or more volts dc from faulted rings—it is intact and there is no damage. If the sheath were damaged and grounded, this battery would drain to ground and not show on the meter. Therefore, the trouble is due to water. The alternatives are limited to farming the cable, purging, or replacing the section.

To determine the extent of water in the cable, the distance-to-strap on a good pair in the section should be measured. This distance should agree with the known physical distance. But what if it does not?

There may be a gauge change in the section. If there is a gauge change, the splice may very possibly be the site of the trouble.

Next the section length should be tested with a capacitance bridge. If the distance measured agrees with the first reading, no water is in the cable, or it's at least confined to a very small section such as a splice. Since water drastically affects cable capacitance, a longer reading on the capacitance bridge indicates water. For example, if the distance-to-strap reading is 700 ft. and the capacitance bridge indicates a length of 1100 ft., there is 400 ft. too much capacitance in the section. Divide this figure by two for an approximate of the amount of water (Figure 1).

Now resistance faults on the conductors can be analyzed and located. The technician should shoot the trouble pairs and note the locations. If the faults appear to be randomly distributed over a length of cable, a length or "slug" of water in the cable at some location other than a splice or encapsulation is indicated.

If the faults appear to be grouped at one or two locations, it is likely there is trouble in a splice or encapsulation.

If the faults are all grouped in one location, with opens indicated, physical damage to the cable is indicated.

When the integrity of the cable sheath is violated, battery will leak to ground at the site of the damage. An earth-gradient device will accurately locate the fault. The entire path of the trouble section should be located because there might be more than one fault.

Once these steps are complete—and it pays to take notes on findings—an accurate picture of the section's condition will emerge.

Representative results

Now that we've seen how section analysis is performed, let's look at a few real-life case histories to see how it's been used and what it's actually been able to achieve.

One case occurred in a section of 900-pair PIC (polyethylene insulated cable) in New Mexico. The section was already up for replacement. Testing showed the faults were grounds, shorts with cross-battery and tips going open. Since no battery was indicated on the shield, a splice failure was suspected.

A test with a resistance fault locator confirmed the physical distance of the section by taking a distance-to-strap reading on a shorted pair. The distance read was 972 ft. with the resistance faults 140 ft. from the pedestal. A capacitance bridge was used to confirm the section distance—showing 980 ft., or no intrusion of water—and a cable and sheath fault locator confirmed shield damage at 140 ft. from the pedestal.

Excavation exposed a splice failure—a boot on the cable had rotted away, exposing the conductors to moisture (Figure 2).

Here's how the procedure helped save money. The estimated cost of replacing the section—\$6306.34 for the cable, \$2808.00 for splices and \$1633.00 for cable placement—came to \$10,747.34.

In comparison, repairing the failed splice cost \$1404.00 for the repair and \$500 for the excavation for a total cost of \$1904.00.

That's a savings of \$8843.34 over the anticipated, but unnecessary, cost of replacement (Table 1).

Another example occurred in a 180-ft. section of 50 pair, 24 gauge PIC in California. Tests showed

grounded shorts, cross-battery, open tips, and no battery on the sheath. The bonds were removed and a VOM (volt-ohm meter) indicated a 150-ohm sheath fault.

A capacitance-resistance comparison was run, and showed a capacitive length of 260 ft. and a correct resistive length of 180 ft. Dividing the difference—80 ft.—by two indicated that there was 40 ft. of water in the section.

Conductor faults were indicated 60 ft. from the hookup. Excavation revealed a bad encapsulated splice at that location. After shorting a pair in each direction, the readings agreed on a distance of 120 ft. out from the original hookup. Shooting back, the resistive measurement was 60 ft., and the capacitive was 120 ft. The water was in that shorter section (Figure 3).

In this case, the operating company saved by installing one-third as much cable as it had first thought necessary. Initially, it had planned to replace the whole section, at a cable cost of \$102.60, \$293.76 for placing it, \$332 for splices, and \$500 for the pit work, at a total cost of \$1228.36.

The 60-ft. section found to actually be necessary after section analysis, however, cost \$34.32, and \$97.92 to place. The entire job was done for \$964.24 (Table 2).

Another example occurred in Colorado. Section analysis was used on a 450-ft. section of 100 pair, 24 gauge PIC, and showed a complete cable failure: all pairs were faulted to ground and shorted. When the shield was isolated, a VOM showed a shield fault of 4500 ohms.

The capacitance bridge showed a
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Table 2**Cost of replacing 180 ft. of cable:**

Cable	\$ 102.60
Placing	293.76
Splices	332.00
Pit	500.00
Total	\$1228.36

Cost of replacing 60 ft. of cable:

Cable	\$ 34.32
Placing	97.92
Splices	332.00
Pit	500.00
Total	\$964.24

Savings:

Replacing 180 ft. of cable	\$1228.36
Replacing 60 ft. of cable	964.24
Savings	\$ 264.12

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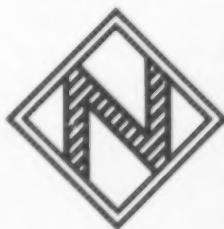


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Table 3

Cost of replacing 450 ft. of cable:

Cable	\$ 411.75
Placing	734.00
Splices (2 @ \$241.00 each)	482.00
Pits (2 @ \$500.00 each)	1000.00
Total	\$2627.75

Cost of replacing 70 ft. of cable:

Cable	\$ 68.82
Placing	122.00
Splices (2 @ \$241.00 each)	482.00
Pits (2 @ \$500.00 each)	1000.00
Total	\$1672.62

Savings:

Replacing 450 ft. of cable	\$2627.75
Replacing 70 ft. of cable	1672.62
Savings	\$ 955.13

cable length of 600 ft., and the resistance fault locator read the actual length. Again, dividing the difference by two indicated that there was about 75 ft. of water in the section.

Conductor faults measured 70 ft. from the test hookup, and the distance was confirmed. Excavation revealed a water-filled lead sleeve.

The cable was opened and readings were taken in both directions. In readings taken to the strap, the capacitance and resistance readings agreed at the actual length of 380 ft. Back to the first hookup site, though, the resistive reading was 70 ft. and the capacitive reading was 220 ft. That was the wet section, and the only part of the cable in need of replacement.

Here's the cost comparison: replacing all 450 ft. of the section would have cost \$411.75 for cable, \$734.00 for placing it, \$482.00 for splices, and \$1000 for pit digging—all at a total of \$2627.75.

Replacing the 70 ft. wet section, though, cost \$68.82 for the cable, \$122.00 for placement, and the same \$1482 for splices and digging, for a total of \$1672.52. That's a savings of \$955.13, or over 36% (Table 3).

In each case the section analysis procedure adds cost over less thorough fault finding techniques—but the amount is not as much as the cost being saved.

And in cases such as the hypothetical example given earlier, bearing a little more cost for troubleshooting and repair up front saves the cost of further cable deterioration, subscriber complaints, and repeat service calls. □